EVALUATION PROGRAM
for
SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST
OF
GULTON INDUSTRIES, INCORPORATED
6.0 AMPERE-HOUR ADHYDRODE CELLS

prepared for
GODDARD SPACE FLIGHT CENTER
CONTRACT W11,252B

QUALITY EVALUATION LABORATORY
NAD CRANE, INDIANA

QUALITY EVALUATION LABORATORY
UNITED STATES NAVAL AMMUNITION DEPOT
CRANE, INDIANA

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ACCEPTANCE TEST OF GULTON INDUSTRIES INCORPORATED 6.0 AMPERE-HOUR ADHYDRODE CELLS

QE/C 67-245 5 MAY 1967

PREPARED UNDER THE DIRECTION OF

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Enclosure (1)

REPORT BRIEF

GULTON 6.0 AMPERE-HOUR ADHYDRODE NICKEL CADMIUM SECONDARY SPACECRAFT CELLS

Ref: (a) National Aeronautics and Space Administration Purchase Order Number W11,252B
(b) NASA ltr BRA/VBK/pad of 25 September 1961 w/BUWEPS first end FQ-1:WSK of 2 October 1961 to CO NAD Crane
(c) Preliminary Work Statement for Battery Evaluation Program of 25 August 1961

I. TEST ASSIGNMENT BRIEF.

A. In compliance with references (a) and (b), evaluation of Gulton Industries, Inc. 6.0 ampere-hour Adhydrode Secondary Spacecraft Cells was begun according to the program outline of reference (c).

B. The object of this evaluation program is to gather specific information concerning secondary spacecraft cells. Information concerning performance characteristics and limitations, including cycle life under various electrical and environmental conditions, will be of interest to power systems designers and users. Cell weaknesses, including causes of failure of present designs, will be of interest to suppliers as a guide to product improvement.

C. Twenty-five 6.0 ampere-hour cells were purchased from Gulton Industries, Inc., Metuchen, New Jersey by National Aeronautics and Space Administration (NASA). These cells are rated at 6.0 ampere hours by the manufacturer and include the adhydrode or adsorption hydrogen type auxiliary electrode.

II. CONCLUSIONS.

A. From the results of this test, it can be concluded that:

1. The ceramic seals of these cells, manufactured by Gulton Industries, Inc. are satisfactory as evidenced by no leakers out of the 25 cells tested.

2. The capacities of the cells were in the acceptable range of 6.99 to 7.41 ampere-hours.

III. RECOMMENDATIONS.

A. It is recommended that these Gulton Industries, Inc. 6.0 ampere-hour adhydrode cells be accepted on the basis of the acceptance test results.

RESULTS OF ACCEPTANCE TESTS

OF

6.0 AMPERE-HOUR ADHYDRODE NICKEL CADMIUM

SECONDARY SPACECRAFT CELLS

MANUFACTURED BY

GULTON INDUSTRIES, INC.

I. INTRODUCTION.

A. On 17 January 1967, this activity began acceptance tests on twenty-five 6.0 ampere-hour cells. These tests were completed on 31 January 1967.

II. TEST CONDITIONS.

A. All acceptance tests were performed at an ambient temperature between 23° C and 27° C at existing relative humidity and atmospheric pressure and consisted of the following:

1. Phenolphthalein Leak Test.
2. Capacity Test.
3. Cell Short Test.
4. Immersion Seal Test.
5. Overcharge Test.
6. Internal Resistance Test of the Adhydrode.
7. Internal Resistance Test of the Cell.
8. Immersion Seal Test.

B. All charging and discharging was done at constant current (±5 percent). Cells were charged in series but discharged individually.

III. CELL IDENTIFICATION AND DESCRIPTION.

A. Cells were identified by the manufacturer's serial numbers which were from 357 to 398, although not consecutively.

B. The 6.0 ampere-hour adhydrode cells are rectangular in shape with average height (base to top of positive terminal), length and width of 3.594, 0.812 and 2.088 inches respectively. The average weight was 281.0 grams. The individual cell dimensions and weight are given in Table I. Figure 1 is a photograph showing the Gulton Industries, Inc. 6.0 ampere-hour adhydrode cell.

C. The cell containers or cans, and the cell covers are made of stainless steel. Both terminals are insulated from the cell covers by ceramic seals and protrude through the cover as solder type terminals.

D. These cells, rated by the manufacturer at 6.0 ampere-hours, were supplied in a discharged (with shorting wire) condition.

IV. TEST PROCEDURE AND RESULTS.

A. Phenolphthalein Leak Test.

1. The phenolphthalein leak test is a determination of the condition of the welds and ceramic seals on receipt of the cells. This test was performed with a phenolphthalein spray indicator solution of one-half of one percent concentration.

2. There were no signs of leakage on any of the 25 cells subjected to the leak test.

B. Capacity Test.

1. The capacity test is a determination of the cell capacity at the c/2 discharge rate, where c is the manufacturer's rated capacity, to a cutoff voltage of 1.00 volt per cell. The discharge was made after a 1-hour open circuit period following the 16-hour charge at the c/10 rate. A total of three capacity checks were made at this activity. The cells were discharged individually, but were recharged in series.

2. In order to gather data on the characteristics of the adhydrode, 51 ohms resistance was used between the adhydrode and the negative terminal for the first capacity check; 24 ohms was used for the second capacity check; and an open circuit or infinite resistance was used for the third capacity check.

3. Since complete capacity data, including adhydrode characteristics with the three resistance values, was not submitted by the manufacturer, it was not possible to compare the manufacturer's results with those of this activity. The individual cell capacities

ranged from 6.99 to 7.41 ampere-hours for an average of 7.25 ampere-hours. The cell capacities together with the adhydrode voltage characteristics are tabulated in Table II. Characteristic 2-hour rate discharge curves are shown in Figure 2.

C. Cell Short Test.

1. The cell short test is a means of detecting slight shorting conditions which may exist because of imperfections in the insulating materials or damage to the element in handling or assembly.

2. Following completion of the third capacity discharge test, each individual cell was loaded with a resistor of value giving a c/1 to c/5 discharge rate and allowed to stand 16 hours with the resistor acting as a shorting device. At the end of 16 hours, the resistors were removed and the cells were placed on open circuit stand for 24 hours. Any cell whose voltage did not recover to 1.15 volts or higher was rejected.

3. The open circuit cell voltages, 24 hours after removal of the shorting resistors, ranged from 1.16 to 1.20 volts for an average of 1.20 volts.

4. There were no rejects of any of the cells subjected to the cell short test. The voltage values for the 25 accepted cells are shown in Table II.

D. Immersion Seal Test.

1. The immersion seal test is a means of detecting leakage of a seal or weld. The test was performed before and after the overcharge test sequence to determine the presence and cause of leaks.

2. The cells were placed under water in a bell jar container. A vacuum of 20 inches of mercury was held for 3 minutes. Cells discharging a steady stream of bubbles were considered rejects.

3. There were no rejects in the 25 cells subjected to the immersion seal test.

E. Overcharge Test.

1. The overcharge tests were performed to determine the steady state voltage at specific rates. The test specified a series of constant current charges at c/20, c/10 and c/5 rates, for a minimum of 48 hours at each charge rate or until the increase of the "on-charge" voltage was less than 10 millivolts per day.

2. The cells were monitored hourly throughout the test. Charging was to be discontinued on cells which exceeded 1.50 volts while on charge. There was no need to remove any cells from the charging sequence.

3. The steady state voltage of each cell at the end of each 48-hour charge rate test is shown in Table II. Characteristic overcharge voltage curves are shown in Figure 3.

F. Internal Resistance Test of the Adhydrode.

1. This test was performed to determine the internal resistance of the adhydrode.

2. During the c/10 charge rate portion of the overcharge test; the voltage drop across the 51 ohm resistor connecting the adhydrode to the negative terminal was measured. The 51 ohm resistor was then shunted with a one ohm resistor for 5 to 10 seconds and the voltage drop across the two parallel resistors (0.9808 ohms) was measured. The internal resistance of the adhydrode in ohms was calculated according to the following formula:

$$R = \frac{V1 - V2}{I2 - I1}$$

where V1 = voltage drop in volts across the 51 ohm resistor
V2 = voltage drop in volts across the 0.9808 ohm resistor
I1 = current flow in amperes through the 51 ohm resistor
I2 = current flow in amperes through the 0.9808 ohm resistor

3. The internal resistance value for the adhydrode of each cell is shown in Table III. The values range from 7.65 ohms to 12.90 ohms.

G. Internal Resistance Test of the Cell.

1. This test was performed to determine the internal resistance of the cell.

2. At the completion of the overcharge test, the cells were returned to the c/20 charging rate and given a short pulse (5-10 seconds) at the rate of c in amperes. The cell voltages, V1, immediately prior to the pulse; and V2, 5 milliseconds after the pulse, were read on a suitable recording instrument. A CEC high speed oscillograph recorder (28.8 inches of tape per second) was used. The internal resistance of the cell in ohms was calculated according to the following formula:

$$R = \frac{V2 - V1}{Ic - Ic/20}$$

V1 and V2 are in volts, Ic and Ic/20 are in amperes.

3. The internal resistance value for each cell is shown in Table III. The values range from 1.75 milliohms to 3.51 milliohms.

TABLE I

Gulton 6.0 Ampere Hour Cells

Cell Number	Height (Inches)	Length (Inches)	Width (Inches)	Weight (Grams)
357	3.575	0.810	2.088	278.9
361	3.600	0.812	2.088	279.7
363	3.593	0.812	2.090	283.5
364	3.590	0.812	2.086	278.8
365	3.600	0.812	2.088	280.2
366	3.603	0.810	2.087	277.2
367	3.588	0.811	2.087	277.6
368	3.611	0.812	2.087	279.9
372	3.596	0.812	2.087	280.0
373	3.596	0.812	2.088	283.2
374	3.612	0.813	2.088	282.6
375	3.591	0.811	2.092	279.4
376	3.608	0.815	2.089	284.2
377	3.610	0.812	2.087	283.2
379	3.580	0.810	2.092	282.0
381	3.604	0.811	2.090	281.9
382	3.587	0.812	2.085	280.5
384	3.600	0.810	2.086	284.3
385	3.596	0.812	2.090	279.6
387	3.584	0.812	2.089	279.9
388	3.588	0.812	2.090	283.8
390	3.586	0.812	2.090	282.8
391	3.588	0.812	2.085	280.5
394	3.592	0.812	2.088	281.5
398	3.576	0.812	2.092	279.9

GULTON 6 A.H. 3RD ELECTRODE

TABLE II

CELL NUMBER	END OF CHARGE WITH 51 OHM RESISTOR		CAPACITY NO. 1	END OF CHARGE WITH 24 OHM RESISTOR		CAPACITY NO. 2	END OF CHARGE WITH NO RESISTOR		CAPACITY NO. 3	CELL SHORT TEST	c/20 OVERCHARGE			c/10 OVERCHARGE			c/5 OVERCHARGE		
	Volts	Amps		Volts	Amps		Volts	Amps			CELL VOLTAGE	THIRD ELECTRODE Volts	Amps	CELL VOLTAGE	THIRD ELECTRODE Volts	Amps	CELL VOLTAGE	THIRD ELECTRODE Volts	Amps
357	1.45	0.0062	6.96	1.45	0.0139	6.75	1.45	0.0	7.35	1.20	1.45	0.399	0.0078	1.45	0.504	0.0099	1.45	0.625	0.0123
361	1.46	0.0077	6.99	1.45	0.0176	6.75	1.45	0.0	7.26	1.20	1.45	0.380	0.0075	1.44	0.510	0.0100	1.43	0.736	0.0144
363	1.48	0.0081	6.99	1.45	0.0171	6.75	1.45	0.0	7.26	1.20	1.43	0.399	0.0078	1.44	0.606	0.0119	1.40	0.818	0.0160
364	1.47	0.0088	6.99	1.44	0.0181	6.75	1.45	0.0	7.35	1.20	1.45	0.419	0.0082	1.43	0.674	0.0132	1.40	0.810	0.0159
365	1.47	0.0085	6.90	1.44	0.0187	6.75	1.45	0.0	7.26	1.16	1.44	0.425	0.0083	1.43	0.718	0.0141	1.40	0.810	0.0159
366	1.48	0.0093	6.96	1.44	0.0184	6.51	1.44	0.0	7.20	1.20	1.44	0.409	0.0080	1.43	0.673	0.0132	1.40	0.813	0.0159
367	1.48	0.0091	6.96	1.44	0.0171	6.51	1.44	0.0	7.14	1.20	1.44	0.351	0.0069	1.43	0.450	0.0088	1.39	0.715	0.0140
368	1.47	0.0086	6.99	1.44	0.0167	6.90	1.45	0.0	7.35	1.20	1.44	0.360	0.0071	1.43	0.500	0.0099	1.40	0.766	0.0150
372	1.47	0.0086	6.99	1.44	0.0173	6.90	1.45	0.0	7.41	1.20	1.44	0.391	0.0077	1.43	0.600	0.0118	1.40	0.815	0.0160
373	1.46	0.0064	7.20	1.46	0.0177	6.90	1.46	0.0	7.41	1.20	1.45	0.410	0.0080	1.44	0.633	0.0124	1.45	0.830	0.0163
374	1.45	0.0062	6.99	1.45	0.0170	6.75	1.45	0.0	7.29	1.20	1.44	0.374	0.0073	1.45	0.469	0.0092	1.45	0.715	0.0140
375	1.46	0.0087	6.99	1.45	0.0175	6.51	1.45	0.0	6.99	1.20	1.44	0.420	0.0082	1.44	0.558	0.0109	1.40	0.803	0.0157
376	1.44	0.0056	6.99	1.45	0.0169	6.75	1.45	0.0	7.29	1.20	1.44	0.359	0.0071	1.44	0.436	0.0085	1.40	0.615	0.0121
377	1.45	0.0083	6.99	1.44	0.0181	6.51	1.44	0.0	7.19	1.20	1.43	0.409	0.0080	1.43	0.592	0.0116	1.40	0.805	0.0158
379	1.44	0.0061	6.99	1.44	0.0167	6.75	1.45	0.0	7.35	1.19	1.43	0.354	0.0069	1.43	0.453	0.0089	1.40	0.649	0.0127
381	1.45	0.0075	6.99	1.44	0.0172	6.75	1.44	0.0	7.29	1.20	1.43	0.346	0.0068	1.42	0.547	0.0107	1.40	0.766	0.0150
382	1.46	0.0084	6.99	1.44	0.0167	6.51	1.45	0.0	7.20	1.20	1.44	0.345	0.0068	1.43	0.446	0.0088	1.40	0.687	0.0135
384	1.44	0.0065	6.99	1.44	0.0175	6.75	1.45	0.0	7.26	1.20	1.43	0.381	0.0075	1.43	0.502	0.0099	1.40	0.740	0.0145
385	1.45	0.0086	6.99	1.44	0.0180	6.51	1.45	0.0	7.14	1.20	1.44	0.409	0.0080	1.44	0.573	0.0112	1.40	0.810	0.0159
387	1.44	0.0078	6.99	1.45	0.0172	6.51	1.45	0.0	7.26	1.20	1.44	0.379	0.0075	1.44	0.456	0.0089	1.45	0.737	0.0144
388	1.44	0.0056	6.90	1.46	0.0178	6.75	1.46	0.0	7.35	1.20	1.44	0.389	0.0076	1.45	0.497	0.0097	1.45	0.790	0.0155
390	1.43	0.0066	6.84	1.45	0.0170	6.51	1.45	0.0	7.29	1.20	1.44	0.390	0.0076	1.44	0.552	0.0108	1.44	0.806	0.0158
391	1.44	0.0082	6.84	1.45	0.0183	6.45	1.45	0.0	6.99	1.20	1.44	0.402	0.0079	1.44	0.560	0.0110	1.43	0.810	0.0159
394	1.43	0.0063	6.84	1.45	0.0180	6.51	1.45	0.0	7.29	1.20	1.44	0.428	0.0084	1.44	0.585	0.0115	1.44	0.820	0.0160
398	1.44	0.0078	6.84	1.45	0.0176	6.51	1.46	0.0	6.99	1.20	1.44	0.420	0.0082	1.45	0.529	0.0104	1.46	0.804	0.0158

TABLE III

Cell Number	Auxiliary Electrode Resistance (Ohms)	Cell Resistance (Milliohms)
357	7.65	1.75
361	10.88	1.75
363	10.44	1.75
364	11.54	1.75
365	10.52	1.75
366	12.38	1.75
367	10.76	1.75
368	12.47	3.51
372	12.38	1.75
373	12.46	1.75
374	8.04	1.75
375	11.12	1.75
376	9.43	1.75
377	11.46	1.75
379	9.23	1.75
381	11.11	3.51
382	9.91	1.75
384	10.33	1.75
385	11.64	1.75
387	11.22	1.75
388	9.22	1.75
390	8.90	1.75
391	11.58	1.75
394	12.90	1.75
398	12.42	1.75

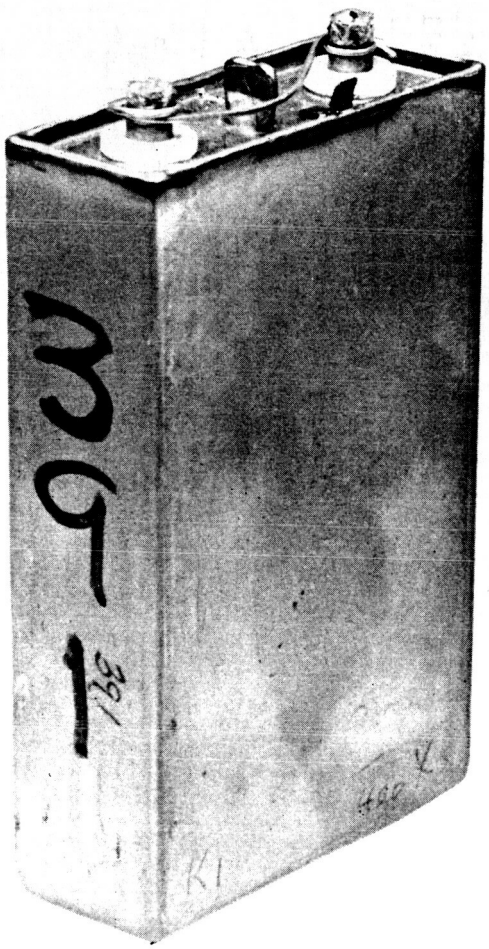
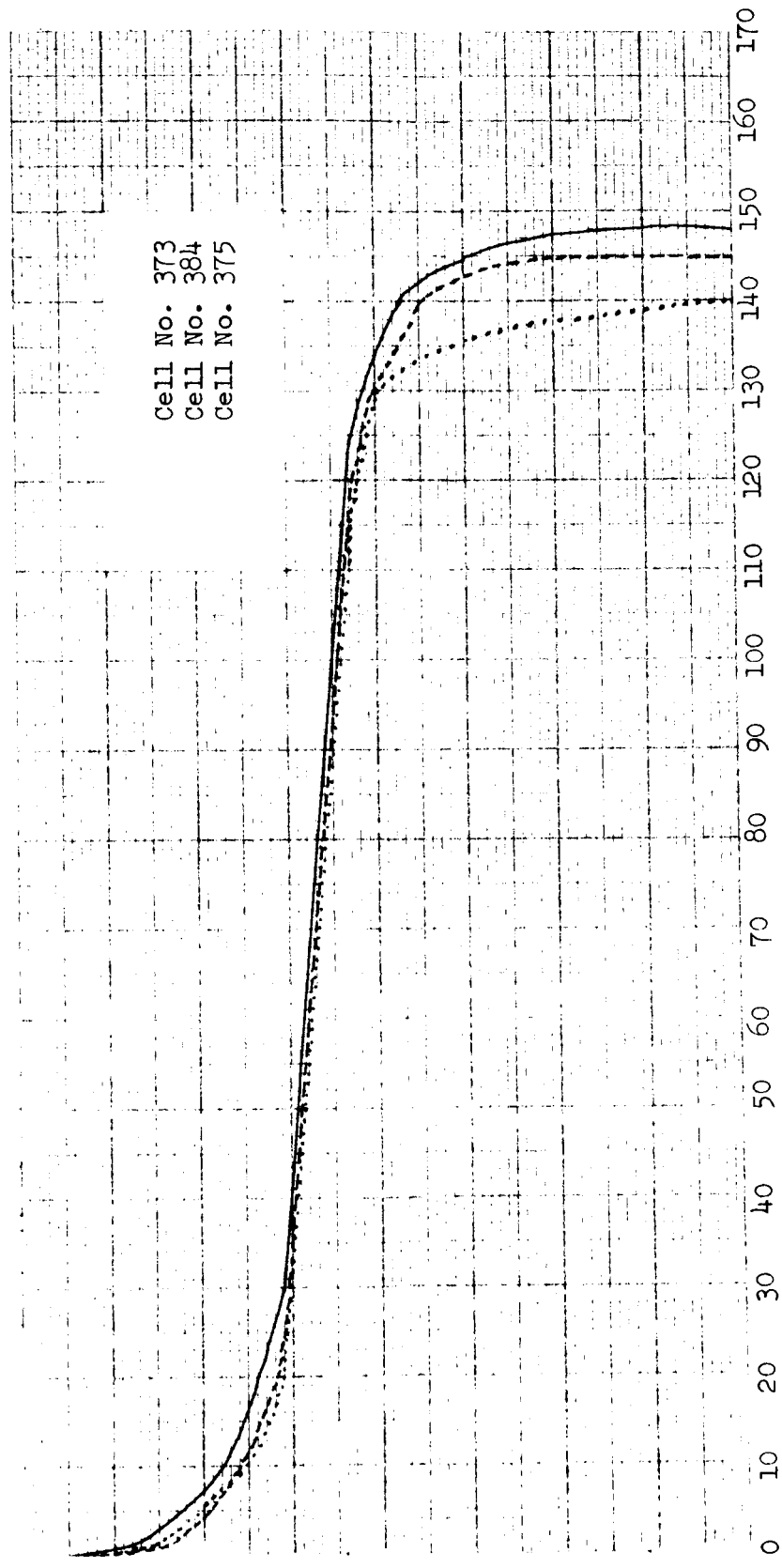


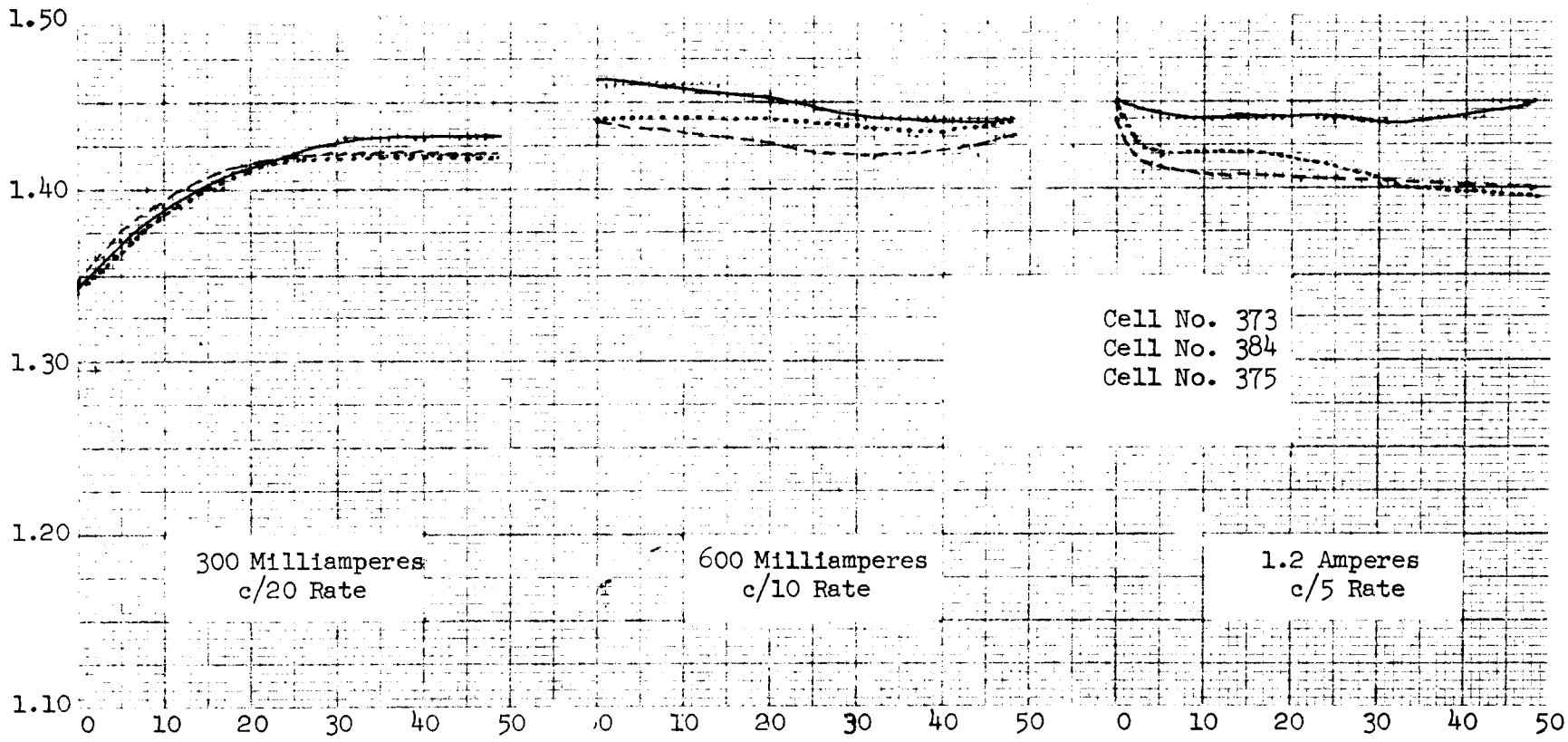
FIGURE 1



CHARACTERISTIC 2-HOUR RATE DISCHARGE

GULTON 6 AMPERE-HOUR ADHYDRODE NICKEL CADMIUM SEALED CELLS

FIGURE 2



CHARACTERISTIC 48-HOUR OVERCHARGE CURVES

GULTON 6 AMPERE-HOUR ADHYDRODE NICKEL CADMIUM SEALED CELLS

FIGURE 3

GE/c 67-245

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66 ChemCell Inc. (Mr. Peter D. Richman), 150 Dey Road, Wayne, New Jersey 07029

67 G. & W. H. Corson, Inc. (Dr. L. J. Minnick), Plymouth Meeting, Pennsylvania 19462

68 Delco-Remy Division, General Motors Corporation (Dr. J. J. Lander), 2401 Columbus Avenue, Anderson, Indiana 46011

69 Douglas Aircraft Company, Inc., Astropower Laboratory (Dr. Carl Berger), 2121 Campus Drive, Newport Beach, California 92663

70 Dynatech Corporation (Mr. R. L. Wentworth), 17 Tudor Street, Cambridge, Massachusetts 02139

71 The Eagle-Picher Industries, Inc. (Mr. E. P. Broglio), P. O. Box 47, Joplin, Missouri 64801

72 The Electric Storage Battery Company, Missile Battery Division (Mr. A. Creitzberg), 2510 Louisburg Road, Raleigh, North Carolina 27604

73 The Electric Storage Battery Company, Carl F. Norberg Research Center (Dr. R. A. Schaefer), 19 West College Avenue, Yardley, Pennsylvania 19067

74 Electrochimica Corporation (Dr. Morris Eisenberg), 1140 O'Brien Drive, Menlo Park, California 94025

75 Electro-Optical Systems, Inc. (Mr. Martin Klein), 300 North Halstead, Pasadena, California 91107

76 Emhart Corporation (Dr. W. P. Cadogan), Box 1620, Hartford, Connecticut 06102

77 Engelhard Industries, Inc. (Dr. J. G. Cohn), 497 DeLancy Street, Newark, New Jersey 07105

78 Dr. Arthur Fleischer, 466 South Center Street, Orange, New Jersey 07050

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83 General Motors Research Laboratories, Advanced Power Systems (Dr. J. S. Smatko), 6767 Hollister Avenue, Goleta, California 93017

84 Globe-Union, Incorporated (Mr. J. D. Onderdonk, V. P. Marketing), P. O. Box 591, Milwaukee, Wisconsin 53201

85 Gould-National Batteries, Inc., Engineering and Research Center (Mr. J. F. Donahue), 2630 University Avenue, S.E., Minneapolis, Minnesota 55418

86 Gulton Industries, Alkaline Battery Division (Dr. Robert Shair), 212 Durham Avenue, Metuchen, New Jersey 08840

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88 Hughes Aircraft Corporation (Mr. P. C. Ricks, Bldg. 366, M.S. 524), El Segundo, California 90245

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96 Livingston Electronic Corporation (Mr. William F. Meyers), Route 309, Montgomeryville, Pennsylvania 18936

97 Lockheed Missiles and Space Company (Technical Information Center), 3251 Hanover Street, Palo Alto, California 93404

98 Mallory Battery Company (Mr. R. R. Clune), Broadway and Sunnyside Lane, North Tarryton, New York 10591

99 P. R. Mallory & Co., Inc. (Dr. Per Bro), Northwest Industrial Park, Burlington, Massachusetts 01803

100 P. R. Mallory & Co., Inc. (Technical Librarian), 3029 E. Washington Street, Indianapolis, Indiana 46206

101 Mauchly Systems Inc. (Mr. John H. Waite), Fort Washington Industrial Park, Fort Washington, Pennsylvania 19034

102 Martin Company, Denver Division (P1001, Mr. R. C. Wildman) Mail No. P-6700-1, Denver, Colorado 80201

103 Midwest Research Institute (Physical Science Laboratory), 425 Volker Boulevard, Kansas City, Missouri 64110

104 Monsanto Research Corporation (Dr. J. O. Smith), Everett, Massachusetts 02149

105 North American Aviation Co., S&ID Division (Dr. James Nash), Downey, California 90241

106 Oklahoma State University (Prof. William L. Hughes, School of Electrical Engineering), Stillwater, Oklahoma 74075

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108 RAI Research Corporation, 36-40 37th Street, Long Island City, New York 11101

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115 Texas Instruments, Inc., Metals and Controls Division (Dr. E. J. Jost), 34 Forest Street, Attleboro, Massachusetts 02703

116 TRW Systems, Inc. (Dr. A. Krausz, Bldg. 60, Room 147), One Space Park, Redondo Beach, California 90278

117 TRW Systems, Inc. (Dr. Herbert P. Silverman), One Space Park, Redondo Beach, California 90278

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